further distance apart, so as to still bring the increased mass of metal in the centre of the coils.

I have been experimenting up to the present time with a view of being able to obtain visual instead of acoustic results, but so far without decided success; the extreme feebleness of the induced current as it approaches its zero-point fails to influence any form of galvanometer; and although the principle can be exhibited by a very sensitive form of galvanometer when a considerable disturbance of the balance takes place, the practical value of the balance is lost by its insensitiveness.

I think I have now explained sufficiently the construction of the apparatus; it is so easily made and used that it should find a place in all future physical researches, and thus by extending its use we may discover its exact value as a new instrument of measurement.

Art. X.—*Notes on the Geology of the West Tamar District, Tasmania.*

By Norman Taylor, of the late Geological Survey of Victoria.

[Read 9th October, 1879.]

The country which I examined in the month of January last contains an area of about forty square miles in the parish of Phillipsnorton, county of Devon, Tasmania. It is situated in the neighbourhood of the West and Middle arms of the River Tamar, a district which at one time gave promise of being a large iron-producing one, but which has, unfortunately, after several trials and much wasted capital, been temporarily abandoned, simply from the unforeseen occurrence in the iron ores of an *oxide of chromium*, the presence of which renders it impossible to turn out good marketable pig iron.

The roughly triangular area, whose base would join the heads of the West and Middle arms of the Tamar, consists at its northern apex of greenstone, rising at Ilfracombe village to a long ridge, capped with older pliocene tertiary

grits and cements. It also forms a range of hills on the north side of the West arm, called Stockyard Hills. This greenstone is followed to the west by rocks of carboniferous age, dipping north-easterly under it, and much obscured (except along the coast line, and at the heads of the arms) by both older and newer tertiary drifts. Further west again follow the silurian rocks, forming ranges of hills, with a general north-westerly trend, against the eastern flanks of which the carboniferous rocks lie unconformably. Beyond these again come the metamorphic rocks. Bays, as it were, of the carboniferous rocks run up the valleys of Anderson's Rivulet and the Middle Arm Creek, the boundary of the two formations (silurian and carboniferous) following a contour line at one general level. The serpentine occupies an oval or lenticular-shaped mass about three miles long by one mile wide, in the valley of Anderson's Rivulet, having its northern extremity near the junction of the silurian and carboniferous formations, and the whole of its length entirely in the former.

I will now proceed to describe the different formations in their order of superposition, from the oldest upwards.

The metamorphic rocks, the lowest and oldest in geological position, form the highest ranges in the district, and the watershed between the River Tamar and the Port Sorell River, and lie at from four to seven miles west of the former river. Their general direction is from N. 20°—30° W., which determines the strike of the other formations and the course of the river. They are chiefly composed of mica schist, quartzite, grit, and clayslate; but, owing to their densely scrubby character, and the prevalence of heavy bush fires, I did not examine them, and will pass to the next formation in ascending order, the lower silurian (of Gould).

This forms a series of nearly parallel ridges, composed of silicious sandstones, grits and conglomerates, micaceous sandstones, shales, slates, and limestones, &c.; the harder indurated silicious rocks forming the summits or backbones of the ridges, the shales and sandstones the flanks of the ranges, and the limestones the valleys. From their association with large limestone belts, I should be inclined rather to class them as upper silurian, in the absence of any fossil evidence of their age. The conglomerate is locally called by the Brandy Creek, or Beaconsfield, miners, "Cabbage-tree," from the range of that name there. The matrix of this conglomerate contains occasionally specks of *chromite* (which is

absent in the enclosed pebbles), and is coloured green by *chrome-ochre*. These ridges are between 300 and 400 feet above sea-level. There are three limestone belts of some importance. One is situated on the Middle Arm Creek, at the Launceston track crossing, and is a white *marble* of fair quality. Another, on the same creek and about half a mile south-west of the last, is a blue or dark grey limestone with *calc-spar* veins. *Gold* is said to have been found in the creek here, and *galena* in the limestone. The third is situated about three miles south-east of Douglass' (the Ilfracombe ironworks), and is similar to the last. There are also three iron lodes in this formation, as well as indications of more. The first is at the north-east end of the Ilfracombe or Blue-peaked Range, and consists of a fibrous and botryoidal *brown hematite* or *limonite* (kidney ore), which seems to be of great extent, but has not yet been opened up. An analysis of this ore in Mr. Newbery's laboratory gave—

Ferric oxide ...	79·34	= 55·54 per cent. of metallic iron.
Silica	15·30	
Combined water	5·16	
	99·80	

Eliminating the silica gives :—

Ferric oxide ...	93·71	= 65·59 iron.
Water	6·09	
	99·80	

Sulphur, phosphorus, and chromium were sought for, but not found.

The second lode is nearly in the centre of the same range, but on its west side at Douglass'. This has been worked by the Ilfracombe Co. to a small extent.

The ore is like the last, and gave on analysis—

Ferric oxide ...	91·14	= 63·94 per cent. metallic iron.
Silica	2·30	
Combined water	6·20	
	99·64	

Eliminating the silica gives :—

Ferric oxide ...	93·29	= 65·30 per cent. iron.
Water	6·35	
	99·64	

Manganese, chromium, sulphur, and phosphorus were specially looked for, but not found.

Pure hydrous oxide of iron should contain 59·89 per cent. of metallic iron, and 14·44 per cent. of combined water. From the water in these ores being present in only about one-third the quantity that it should be, it would seem that the ores are a mixture of the anhydrous oxide *(red hematite)* and the hydrous oxide *(limonite)*. The third lode is at the limestone quarries last mentioned, and has not been worked. There is a doubt about the age of the second lode (at Douglass'), and it is possible that, when properly explored, it may prove to be an ore-bed of carboniferous age. These lodes are all more or less at right angles to the prevailing strike of the rocks bounding them. Other smaller outcrops occur, but are not of much importance.

Mr. Gould's theory that the "iron deposits and outcrops are referable to one line of force, determining lines of fracture, which, in the sandstone and grit formations, have been filled with crystalline brown hematite, and, in the serpentine, with magnetic oxide," will not hold good, as he has evidently suited the position of these deposits and outcrops on his map to his theory. His supposed line of fracture is a north-west one, in the strike of the country, and the true lodes are nearly all east and west, or almost at right angles to the strike; whilst the ironstone deposits, mentioned further on, are undoubtedly tertiary cappings, which may or may not have connection with lodes below, of which, however, there is no evidence other than the occurrence of masses of *magnetic iron* in the *limonite*.

The only reefs known to be auriferous are those at Brandy Creek—but at the time of my visit the only reef yielding good returns was the celebrated "Tasmania." Other reefs struck payable-looking stone, but had to wait the advent of a long-promised crushing company.

In the area occupied by *serpentine*, the highest hills consist at their summits of a coarse or fine-grained glittering black rock—a gabbro, composed apparently of a triclinic *feldspar* and brown *mica*, or perhaps *diallage*. These points, of which there are six or seven, are scattered unconnectedly round Mount Vulcan. The gabbro passes rather abruptly, on the flanks of the hills, into a very uniform, both in texture and colour, deep green, oily-looking, semi-translucent rock, with bluish opaline veins, showing rarely traces of lamination, or seeming bedding planes, which have

the same direction as those of the adjoining silurian rocks; below which, and in the valley, the rock loses all traces of stratification, and occurs in a great variety of forms of very variable composition. It is full of veins of *chrysotile*, an analysis of which in Mr. Newbery's laboratory, by Mr. Frederick Dunn, gave—

Silica	43·55
Magnesia	38·04
Protoxide of iron	6·41
Lime	traces.
Alumina	
Water (combined)	11·67
	99·67

Occasionally grains of *chromite* and *magnetite* are thickly distributed in layers. *Magnetite* also occurs in thin veins, and unconnected, striated, or longitudinally grooved slabs, with *asbestus* lying in the external grooves. The decomposed rock often contains veins and nodules of *wad* (hydrous oxide of manganese). Singularly enough this mineral is never seen in the undecomposed rock. From a shaft on the top of Mount Vulcan, the rock contains thin veins of a mamillated, apple-green, soft, waxy-looking, translucent mineral, which, by a blowpipe determination by Mr. Morley, proved to be *genthite*, or silicate of nickel, a somewhat analogous occurrence to the nickel ores of New Caledonia. All the rain channels off the serpentine hills contain minute, glittering, black octahedrons of *chromite* and *magnetite*. A small feldspathic or euritic granite dyke traverses the centre of the serpentine in the usual strike of the country. On the east side of the serpentine hills there is a variable amount of local attraction from north towards west.

The carboniferous rocks, consisting of nearly horizontal conglomerates, sandstones, limestones, &c., occupy generally all the low levels round the western arms of the Tamar. They rest against the flanks of the silurian ranges, pass under the greenstone, and reappear again on the eastern side of the river on the eastern flanks of the Tippagory Ranges, where the eastern edge of the basin rests against silurian rocks in the same way as its western edge does. This formation includes some valuable beds of limestone, exceedingly rich in fossils. A totally unconnected occurrence of these rocks is on the high divide separating the head

waters of Middle Arm Creek from those running south in the neighbourhood of the Ilfracombe lode.

The question as to whether or not *coal* is likely to be found in the district is an exceedingly puzzling one. Very little, if any, prospecting for it has been done; but just before leaving Tasmania I heard of a 15-inch seam having been found a few miles south of Exeter, higher up the River Tamar, on John Plummer's ground, north of Rosefairs, but I had no time to examine into the reliability of the statements made.

The country to the east of the river consists of greenstone, with underlying carboniferous rocks, but Mr. Gould's map gives no indication of any coal seams.

Coal occurs on the Mersey, Don, and Forth rivers to the west, and at Fingal and Mt. Nicholas to the east. The Fingal coal measures are overlaid by greenstone and underlaid by upper palœozoic marine beds, containing fossils identical with those in the district I am describing. The seams are from six to eight feet thick, but the coal is of indifferent quality. The Douglass River coal is of better quality, but the percentage of ash is high. In Mr. Gould's report on the Mersey River coalfield, dated 29th October, 1861, page 7, he states, in regard to the Denison colliery, that "A dark blue clay, slightly calcareous, and intermixed with sand and mica, is thrown *down*, by a large fault, against the coal seam. It is highly fossiliferous, containing *orthonota, spirifera, pachydomus, fenestella, encrinites*, &c., &c. From this and other lithological differences in the strata, it appears that the coal here *underlies* the fossiliferous beds; at Coal Creek, the Mersey Coal Company's shaft was sunk entirely through fossiliferous beds. The seams are greatly faulted."

The fossiliferous marine beds south of Yorktown would, by a calculation of their dip, supposing no faulting to occur, underlie the British and Tasmanian Charcoal Iron Company's works at Port Lemprière by over 5000 feet; but it is evident by an inspection of the dip of these beds at different localities that such a fault or faults must occur. The angle of dip varies very greatly, being larger at the edges of the basin where the rocks are tilted up than towards the centre at Middle Arm. At Middle Island the dip is reversed, so that the thickest part of the basin is probably in the neighbourhood of Port Lemprière.

Of the greenstone little need be said. It has been spread

out like a lava sheet, at what time it is impossible to say. It is not interbedded here, but is, I believe, in the Fingal district; and, if so, it is of carboniferous age. Its only covering in this district now is a tertiary drift, although an older one may have been denuded away. It occupies a very small area, but is largely represented to the east of the river.

An older pliocene tertiary drift, derived from the denudation of the silurian rocks and their contained reefs, covers the entire area of the higher portions of the low country between the two arms, almost completely obscuring the underlying rocks. It also caps the silurian and serpentine hills up to elevations of nearly 300 feet above sea level, between the Cabbage-tree Range and Anderson's Rivulet. It is very widely spread; but I have little doubt but that "leads" would be found, if looked for, in some portions of it. The Italian's and Scotchman's Company tunnelled into it on a head of Brandy Creek, west of the Cabbage-tree Range, and struck a "lead," with good prospects, but were driven out by water. "Made hills" occur along the valleys of the Yorktown and other creeks running up into the silurian and metamorphic ranges.

The ironstone hills, Mounts Vulcan and Scott, and Barnes' Hill, as well as other small outliers, would appear to belong to this period. Of the latter, the Tamar Company's ironstone, being off the serpentine, and free from *chromic iron*, yielded very fine pig iron, but is now worked out. Mounts Vulcan and Scott, the property of the British and Tasmanian Charcoal Iron Company, are situated about five miles southerly from their works at Port Lemprière, with which they are connected by a railway. Mount Vulcan is 278 feet above sea level, and consists of more or less decomposed serpentine. The iron ore (*limonite*) is evidently of tertiary origin, filling a pocket or depression on the north sides of the hills similarly to many European deposits. The top of the hills is covered with an agglomerate of ironstone pebbles, which are polar-magnetic, and the flanks with flat, striated pieces, from a quarter to half an inch or more thick, of *magnetite*, derived from veins already mentioned. The striations or grooves of the *magnetite* correspond with and run in the same direction as the *asbestus* fibres enclosing it. In some larger blocks of *magnetite*, occurring in the *limonite*, the grooves, instead of being straight, are much twisted, and resemble the foliations of metamorphic schists. Some of the

magnetite is polar-magnetic, some simply magnetic. The flat pieces are all magnetic; but one specimen was polar-magnetic at right angles to the striations. The massive *limonite* occurs in large irregularly rounded blocks, imbedded in a ferruginous gravel. It becomes more compact in depth, and has an average thickness of about twenty feet. Borings on Mount Vulcan were stated to have passed through strong lodes of *magnetic* iron; but some shafts put down by Mr. Scott, the Company's manager, and myself, proved their utter unreliability, as no *magnetite* was met with at considerably below the depths stated. The chromium occurs in the *limonite* in the form of *chromite* or chromate of iron, as glittering black specks, and seems to be in the largest quantity in the densest ore. The *magnetite* does not appear to contain chrome. At Barnes' Hill there is a very large extent of ore of a similar character to that already described. A peculiarity of it is that all the surface specimens of *limonite* were more or less magnetic, though I failed to detect any *magnetite*, as at Mounts Vulcan and Scott.

Mr. Gould supposes these ironstone deposits to be the "backs" of strong lodes of magnetic iron ore, and that the drift of *magnetite* on the flanks of the hills points to the existence of veins of magnetic oxide of some size. This may or may not be the case; but the ironstone is, I think, a secondary product, formed by deposition from ferruginous waters issuing as springs round the shores of the then arm of the sea, when the land was at a much lower level, and the gabbro was undergoing metamorphism into serpentine by the process of double decomposition described by Dr. Sterry Hunt. The chromium has been picked up, together with the sand the ore contains, during the contemporaneous formation of the ore and the denudation of the neighbouring hills. The ores vary from ferruginous grits to solid *limonite;* cavities between the denser ore bands are filled with ochreous clay and quartz grains, and the ore is concretionary. The boulders of solid ore have probably once belonged to a solid mass, which, in cracks and joints, has undergone partial oxidation and decomposition *in situ*, the looser gravel and ferruginous ochery clays being the result. Wherever ironstone occurs off the serpentine it contains no chromium.

This ore produces a metal much resembling "spiegeleisen," or manganese iron, and makes good steel, but the percentage of chromium is too high for pig iron. In the present state of metallurgical science, chromium cannot be

separated on a large scale economically from the ore, and it forms in smelting two or more definite chemical compounds in the pig iron, which render it very hard and brittle. The chromium compounds obtained from the Company's pig iron formed the subject matter of a paper by Mr. J. Cosmo Newbery, B.Sc., and Mr. Frederick Dunn, read before this Society on 12th December, 1878.

On the east side of the Brandy Creek, or Cabbage-tree Range, there occur some small leads, consisting of a reef-wash from the "Tasmania" reef, which probably belongs to the older middle pliocene period. Brown's party were on good gold at a depth of 60 feet; while, only about one and a half chains to the east, the Grand Junction Company were down 118 feet without bottom, showing the existence of a ledge between the two, with a very steep vertical fall.

Several companies were at work sinking for a supposed "deep lead" along the eastern foot of the Cabbage-tree Range, with very contradictory results. The height of the surface is about 75 feet above sea level. The Ophir Company had sunk 100 feet, and had passed through a fine white fireclay and a thick bed of *lignite*, containing a small quantity of *iron pyrites*, some quartz pebbles, and numerous fossil fruits, some of which have been recognised by Baron Von Müeller as *Spondylostrobus Smythii* (Müeller), which occurs in the "leads" at Nintingbool (Haddon), Beechworth, and Tangil in Victoria, and at Orange in N. S. Wales; *Conchotheca turgida*, occurring at Haddon and Tangil in Victoria, and at Orange and Darling Downs in N. S. Wales; and *Platycoila Sullivani*, occurring at Tangil in Victoria, and Orange in N. S. Wales. Some leaves were also found, but have not yet been described. Fossil fruits were also found in the Union Company's ground. Although all the claims are situated within 15 chains of the "Tasmania" tunnel, some have lignite, and are tolerably dry (Ophir); others with lignite are very wet (Union); some have no lignite (the Working Miners' Company, only 3 chains south-east of the Ophir) and much water; and others were nearly dry. None of the companies had then bottomed, and some were over 60 feet below sea-level. The flat country, from the foot of the ranges, has probably been an estuary in later tertiary times, and local deposits of lignite have been formed in sluggish tidal inlets, cut out at the junction of the silurian and carboniferous rocks, since which there must have been considerable subsidence. Some boring was being done to the north-east of

Brandy Creek, with, I should imagine, but very slight prospect of obtaining anything, except perhaps coal. They also had met with some lignite. These lignite beds probably belong to the newer middle pliocene period.

To the newer pliocene period may belong the creek "leads" on both sides of the Cabbage-tree Range, and also the extensive wash of pebble drift of various kinds, mixed with angular quartz and "cement," over the low country—a drift derived from the disintegration and denudation of the older tertiary hill cappings, and the underlying rocks where exposed. An old creek bed of this age probably connects two angles of Anderson's Rivulet in the village of Leonardsborough, and may be auriferous.

Concretionary ironstone crops out on the west side of the Middle Island, with a N. 10° E. strike, and an apparent easterly dip under the greenstone. A similar concretionary and rather sandy ironstone, with ochreous kernels, occurs in loose boulders all round the arms at high-water mark, and as a thin bed on the beach south of Ilfracombe village reserve. It seems to be the remains of a pre-existing deposit, resting upon the carboniferous rocks. Its age is doubtful.

Immediately in front of Dowlin's Hotel at Brandy Creek is a bed of *limonite* about 12 chains long by 5 chains wide, and of unknown thickness, from which issues a fine spring of water, flowing all the year round; the ironstone having probably the same origin as that at Mount Vulcan, although, perhaps, of later date.

In conclusion, I will briefly mention one or two other occurrences in connection with the reefs of Brandy Creek. Victorian reefs in general run in, or nearly so, the strike of the country; but here they make an angle of from 30° to 40° with the strike, or nearly east and west. The often-occurring carbonaceous or black schists forming the casings in many Victorian reefs are here represented by a brown, sometimes hard and silicious, and at other times earthy-looking, light and friable sandstone, containing distinct plant impressions, in the softer rock sometimes converted into *coal*. This occurrence has not been hitherto noticed, and is of great interest. This bed is said to form the hanging wall, in connection with the "Cabbage-tree" conglomerate, of the "Tasmania" reef, and I obtained specimens from their top shaft. The same rock also occurs in the shaft of the Providence Company on the top of the range. In